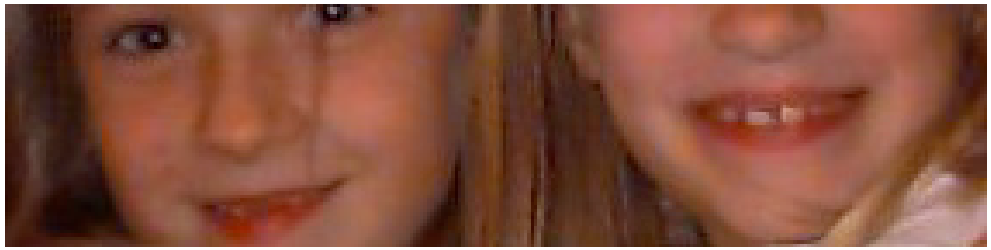
Rapidity gaps in Heavy Ions Collisions at RHIC and the LHC

- Features of Heavy Ion collisions
- forward detectors at RHIC and LHC
- Ultra-Peripheral Collisions
- ATLAS plans



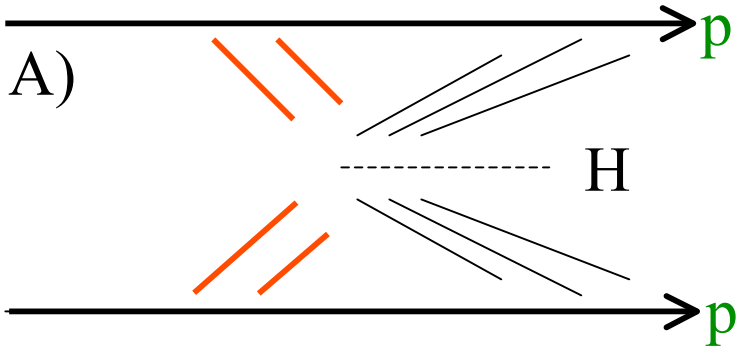
S.White, small-x Workshop 9/19/3

PHENIX

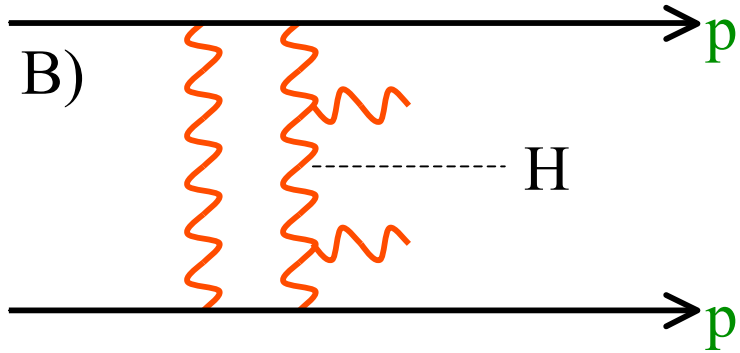
BROOKHAVEN NATIONAL LABORATORY

Models

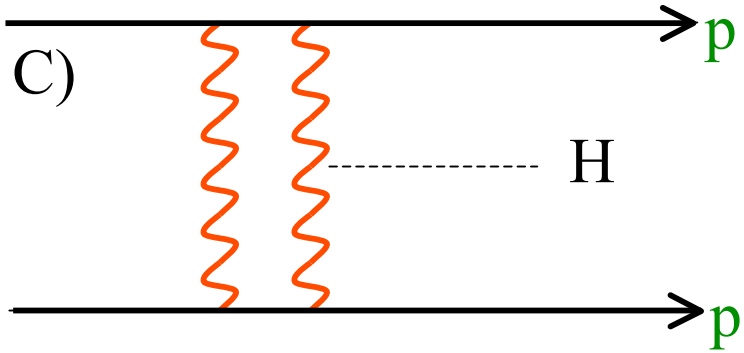
QCD inclusive, factorized



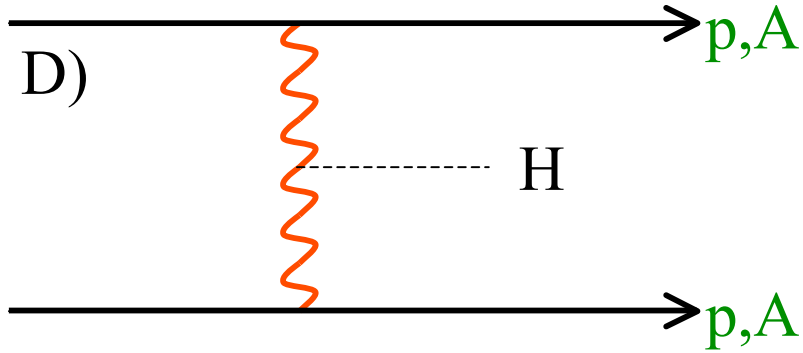
QCD inclusive, non factorized



QCD exclusive



QED exclusive



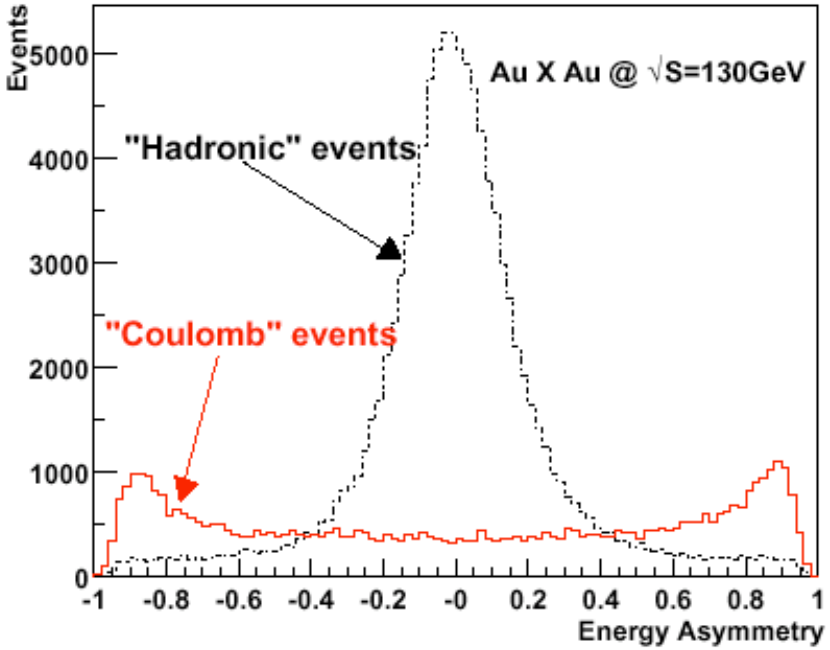
(from m.Boonekamp)

Tag probability high in Heavy Ion events

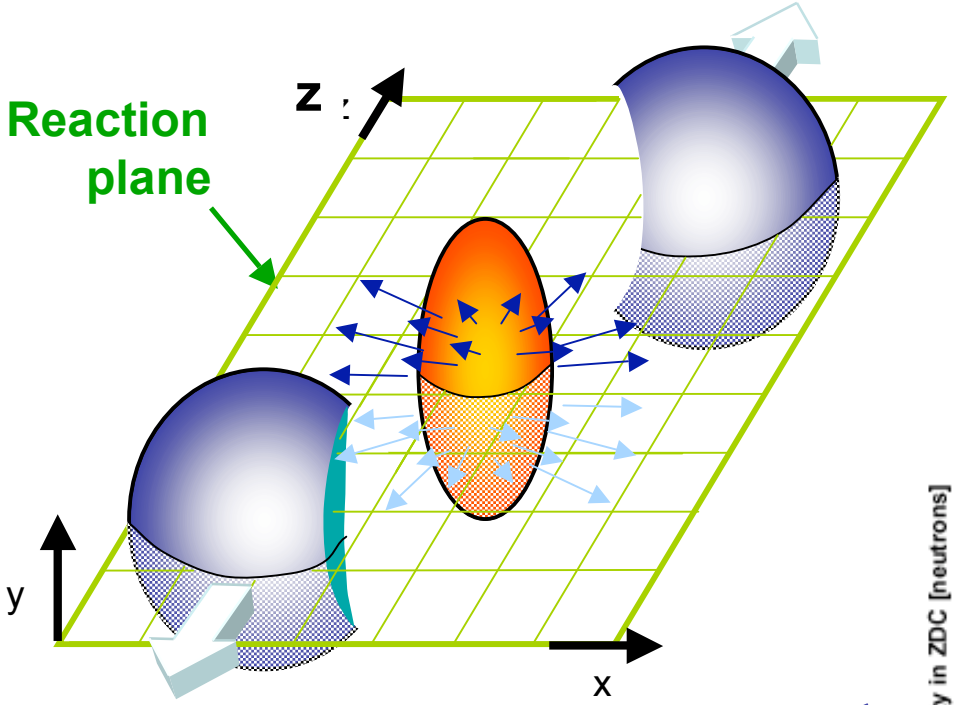
Cross section	STAR (mb)	Ref. [5] (mb)
$\sigma^{\rho}_{xn,xn}$	$28.3 \pm 2.0 \pm 6.3$	27
$\sigma^{\rho}_{1n,1n}$	$2.8 \pm 0.5 \pm 0.7$	2.6
$\sigma^{\rho\,(\text{inc. overlap})}_{xn,xn}$	$39.7 \pm 2.8 \pm 9.7$	...
$\sigma^{\rho}_{xn,0n}$	$95 \pm 60 \pm 25$	...
$\sigma^{\rho}_{0n,0n}$	$370 \pm 170 \pm 80$	...
$\sigma^{\rho}_{\text{total}}$	$460 \pm 220 \pm 110$	350

STAR, fraction as expected from factorization cp. RHIC MCD paper

Beam fragmentation
Un-correlated in tags from Coulomb interactions



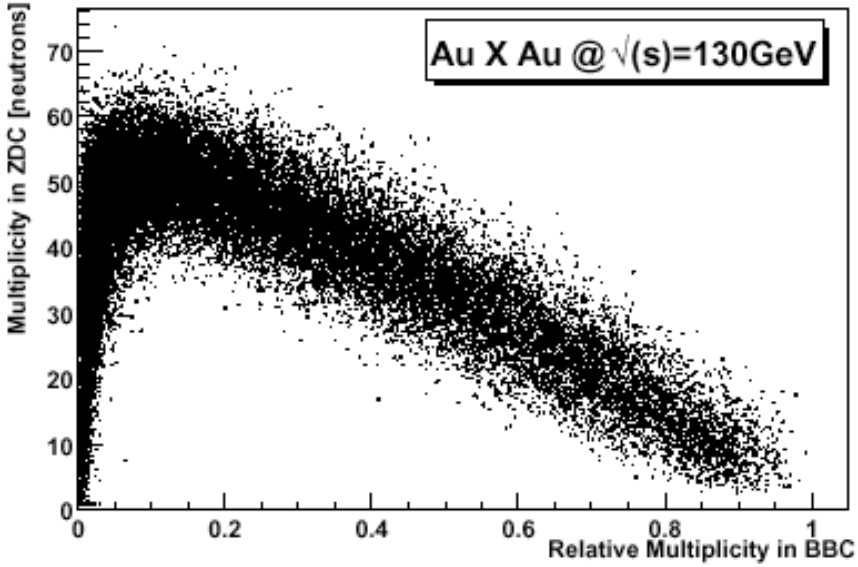
Orientation of reaction plane and Centrality are key observables in Recent papers from RHIC



b direction from BBC
(3<η<4 hodoscope array)

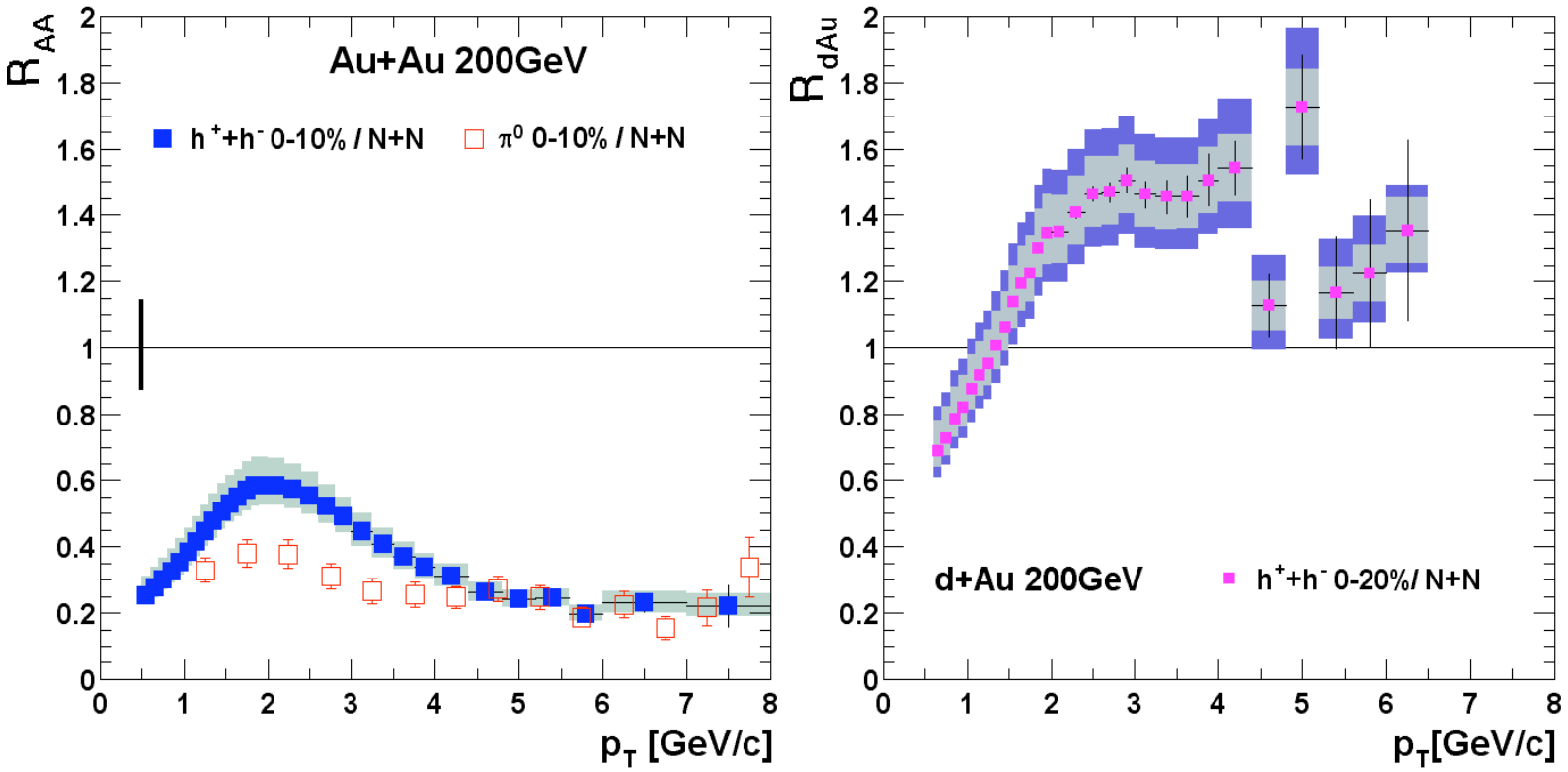
Spectator neutrons
•measure centrality,
•Min_min_bias trigger

(Calorimeter@η<2mr.)

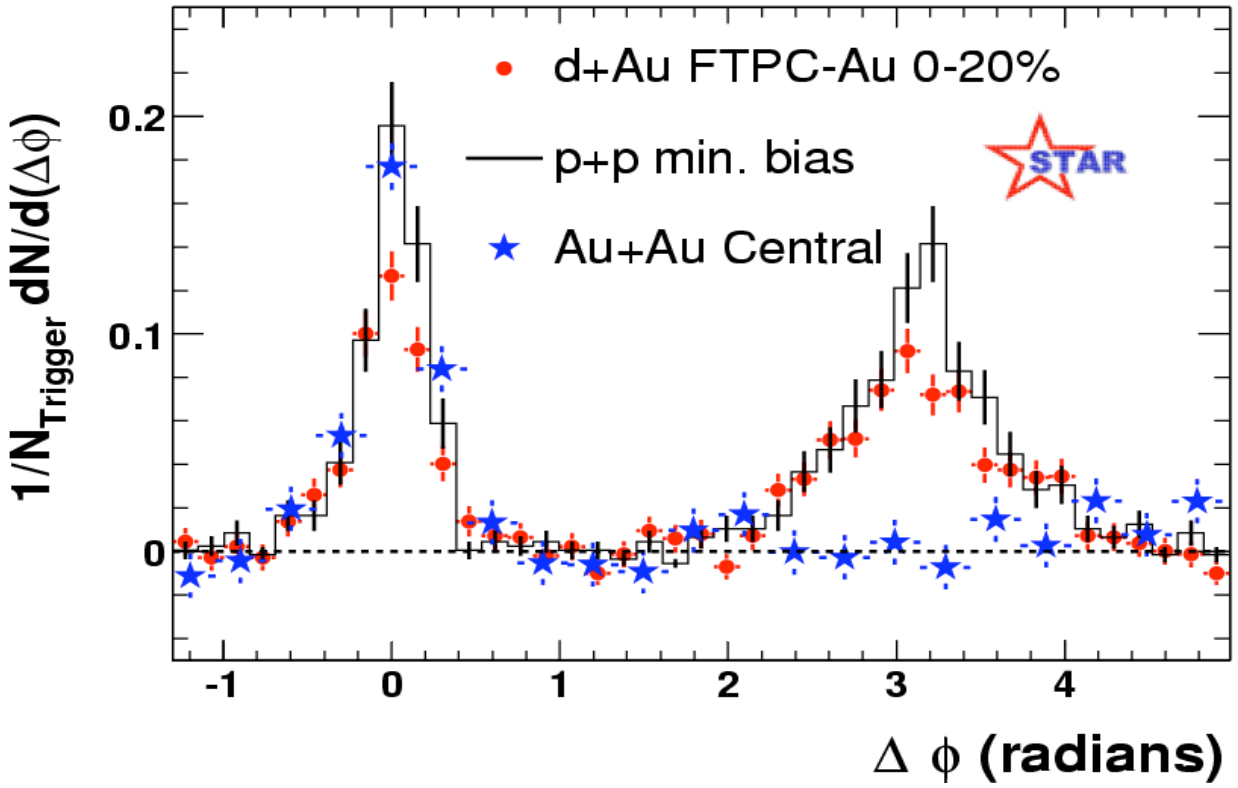


Beam-Beam Counter Mult/1000

Evidence for Jet Suppression at RHIC(PHENIX)

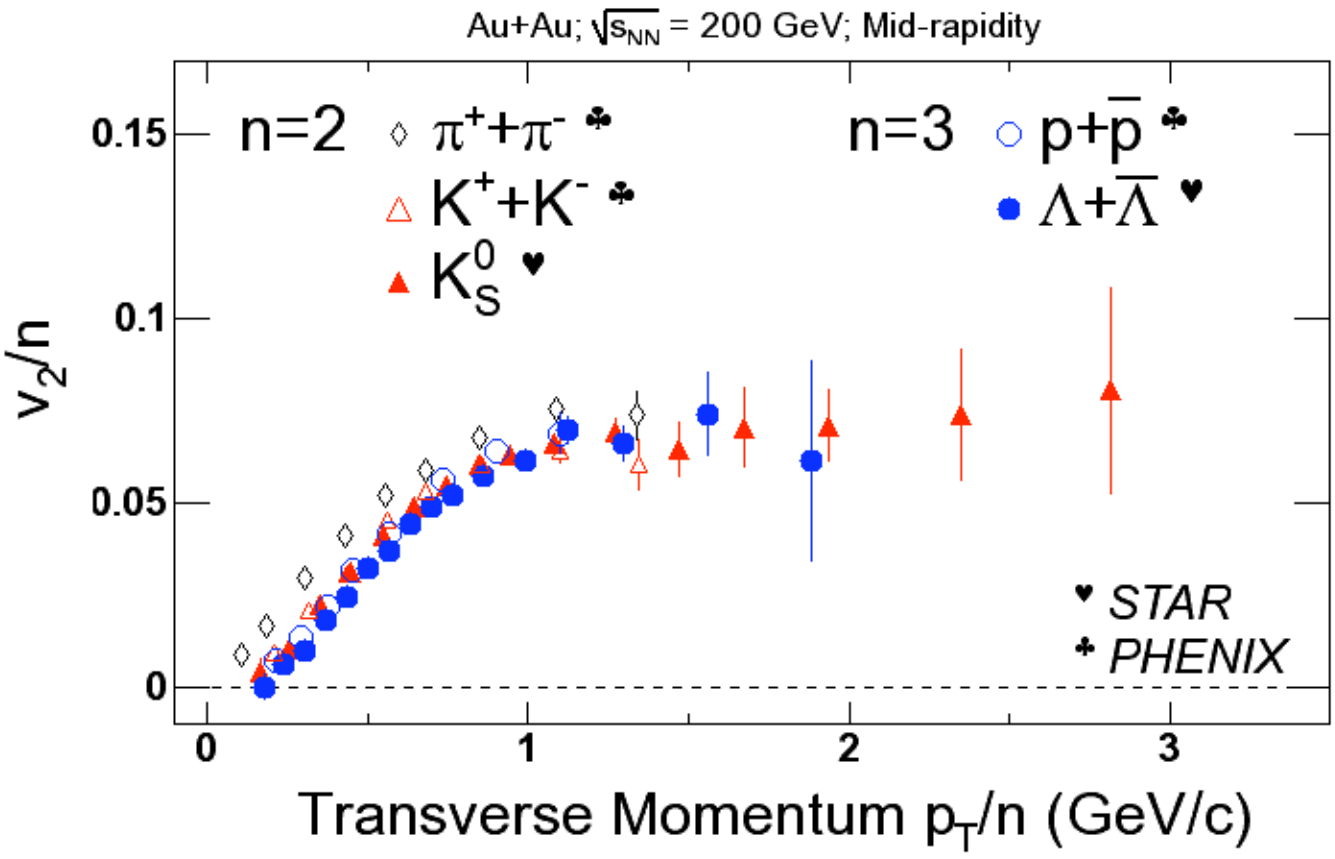


… and disappearance of “away side” jet(STAR)



Scaling of elliptic flow (meson vs. baryon)

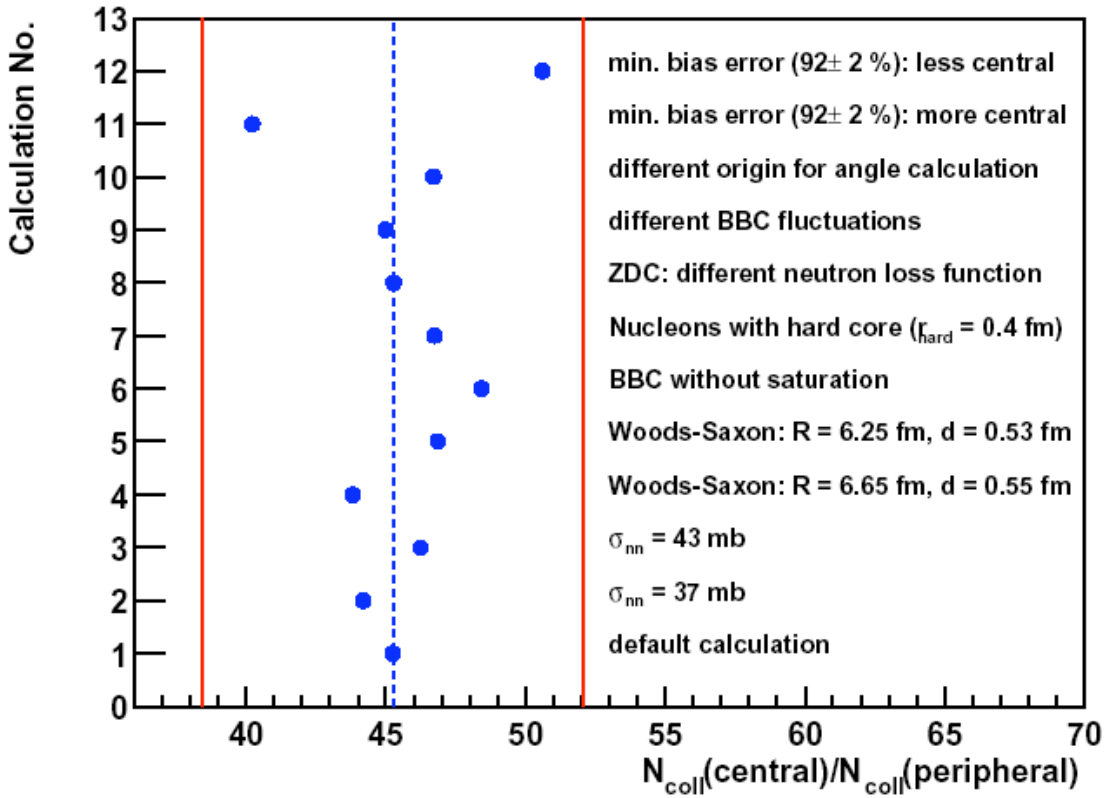
$dn/d\phi \sim 1 + 2\, v_2 \cos(2\phi)$



AA cross-normalization with pp

1) From pp comparison data
   - Error from AA &pp Luminosity uncertainties and $_{\text{ncollision}}$

2) From central/peripheral
   - Error from determination of centrality classes

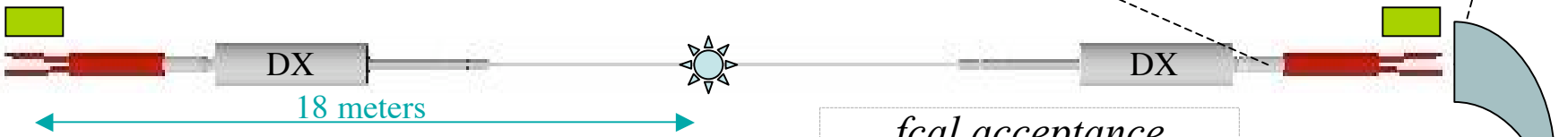


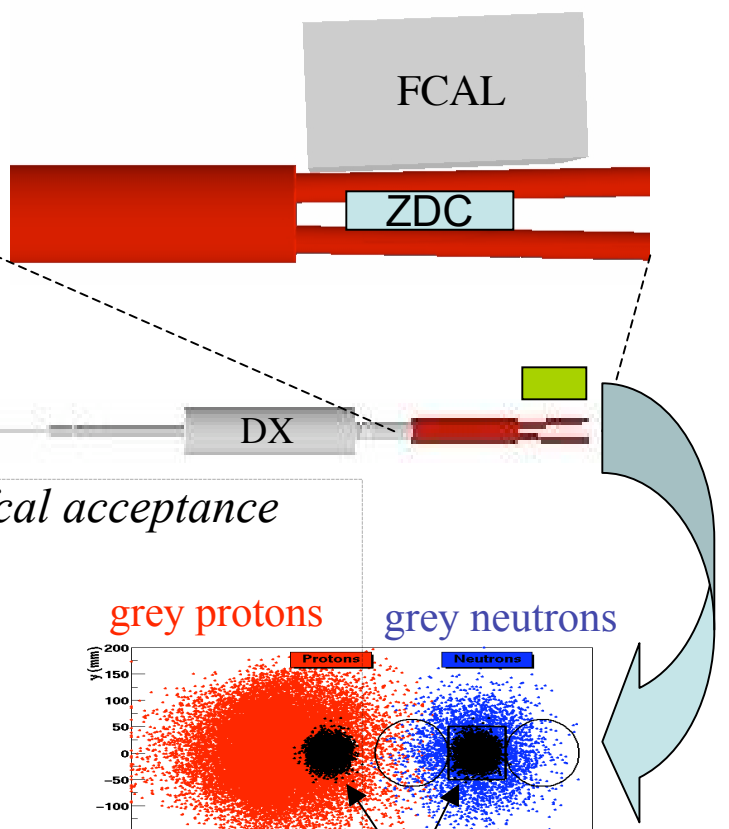
<- *Klaus Reygers, PHENIX internal note 7/01*

PHENIX forward cals in ‘03

DX magnet and layout similar to TAN

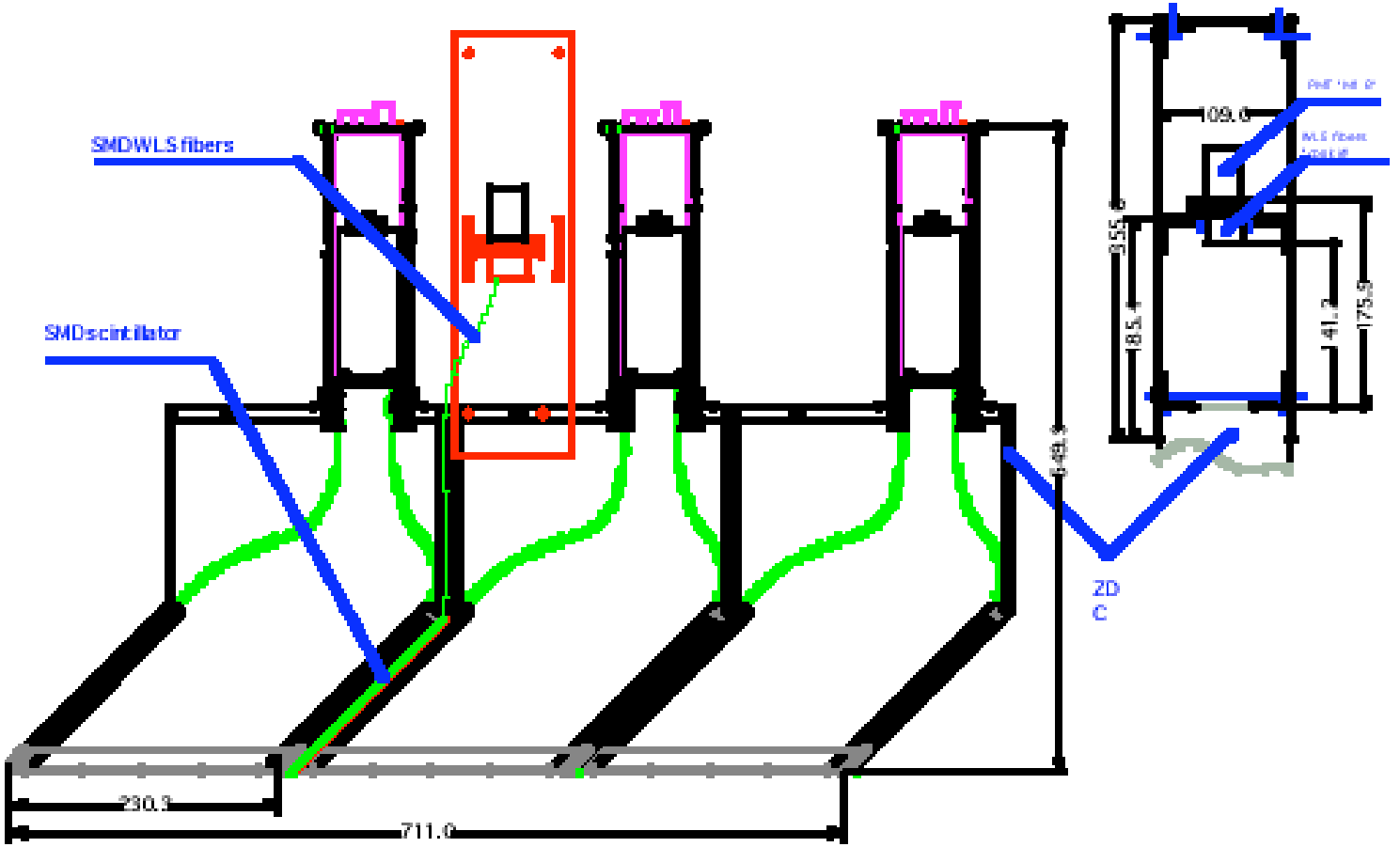
- Z-->(2.7Tev/0.1 TeV)*Z
- X,Y -->(~1)*X,Y





- ZDC in all experiments since day-1
- PHENIX has ZDC shower max@2*λ_I
- “ “ FCAL for d-Au run

ZDC + SMD assy.

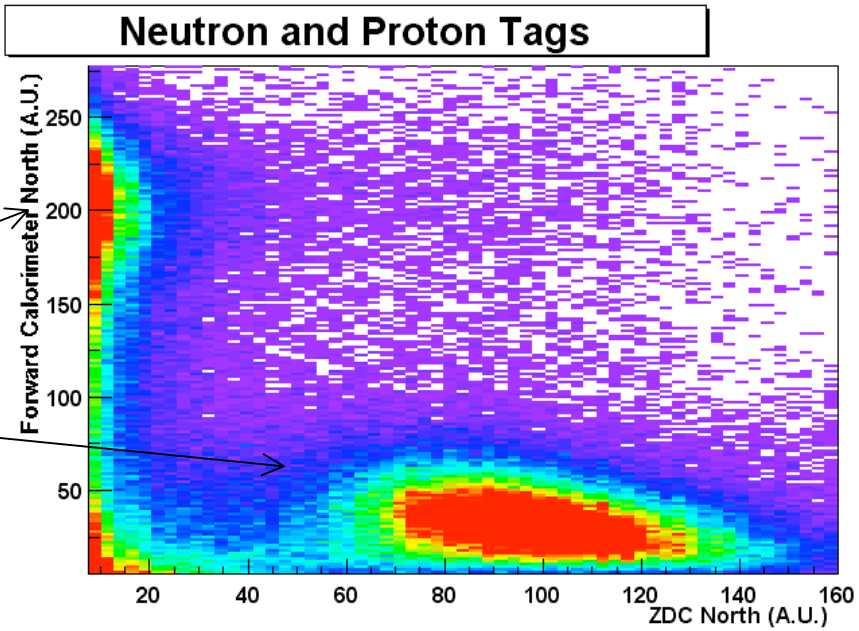

SMDWLS fibers
SMDscintillator
109.0
355
185
41.2
175.5
ZD
C
230.3
711.0

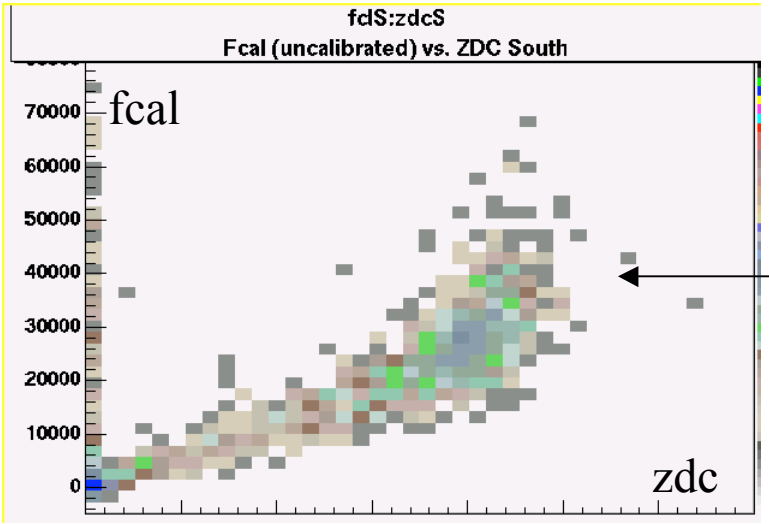
FCAL complements ZCAL centrality measurement

Run 3, d-Au data

single proton in FCAL (n-Au events)

single neutron in ZDC (p-Au events)





Strong correlation on Au-side

(Absolute Luminosity in Heavy Ion mode to <5%)

Calculated cross sections for PbPb@LHC

A.J.Baltz, C.Chasman and SNW NIM A417(1998)p.1

$\sigma_{1n,1n}$	0.537 barns
$\sigma_{1n,xn}$	1.897
$\sigma_{xn,xn}$	14.75
σ_{xn}	227.3

2)Machine based

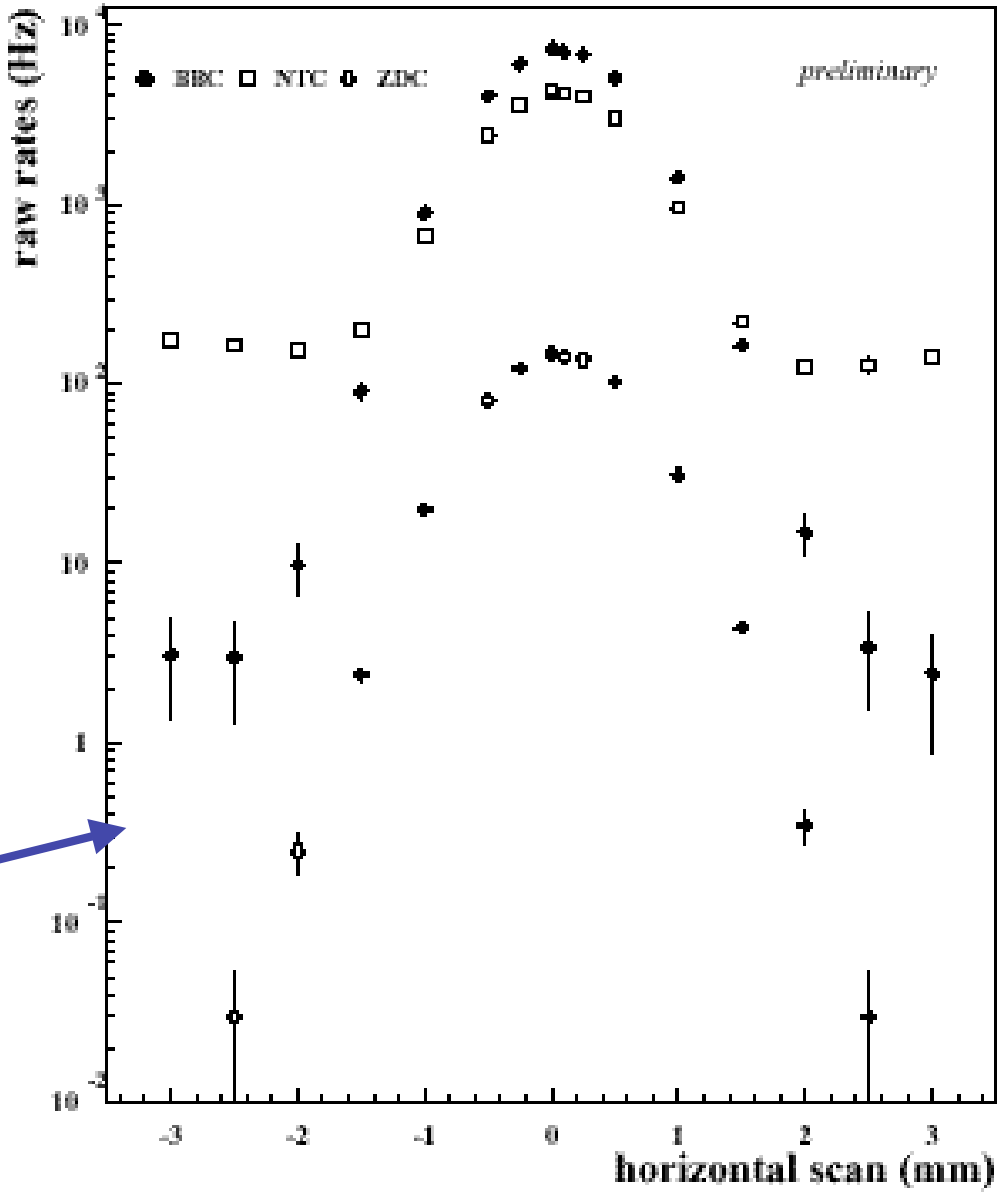
$$L = \frac{3 f_{rev} \square N_b N^2}{2 \square\square^*}$$

$N_b = 56$; $N = 1 \square 10^9$;

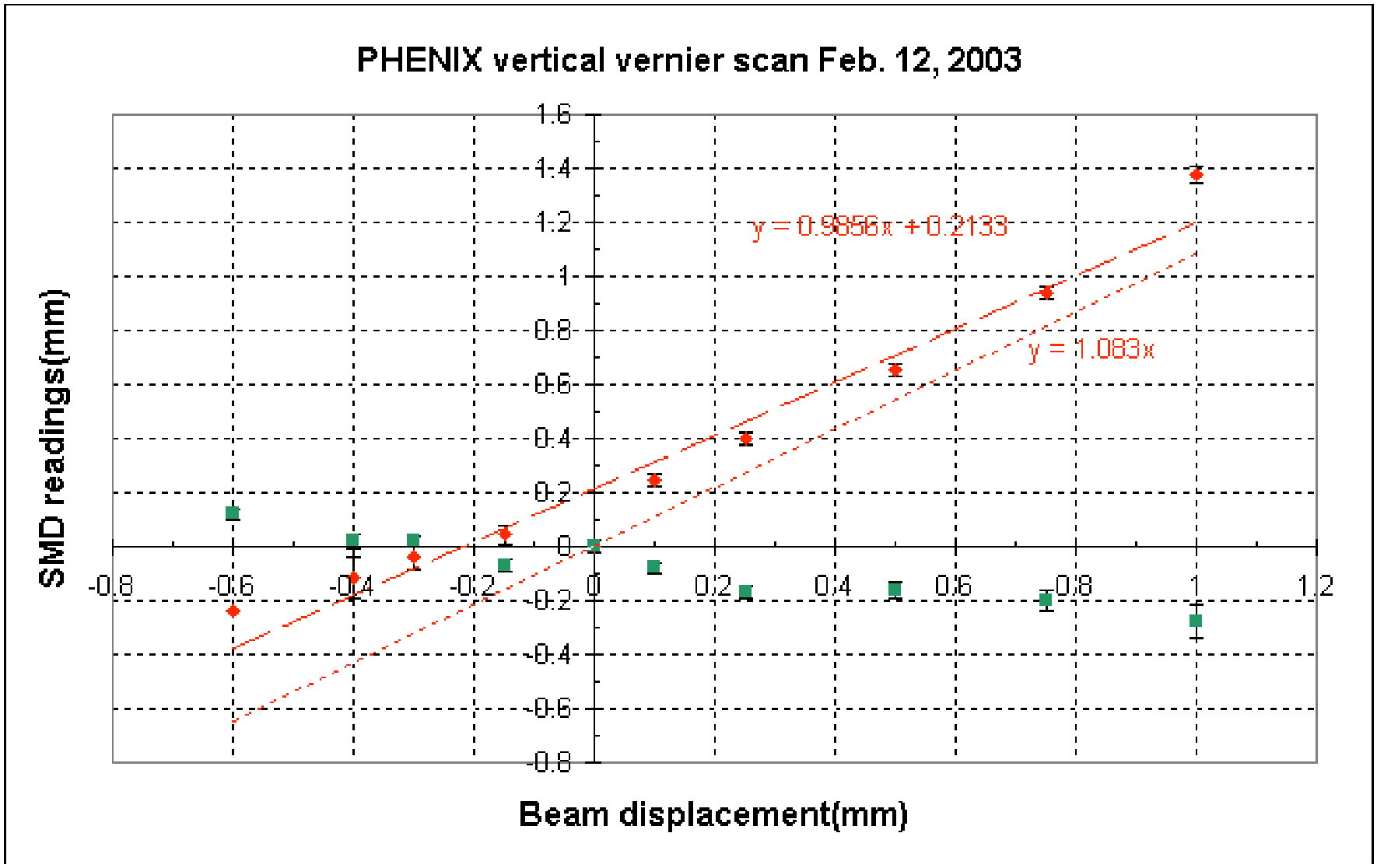
$\square$ = 15 to 40 $\square m$m;

$\square^* = 1 \square 10$m

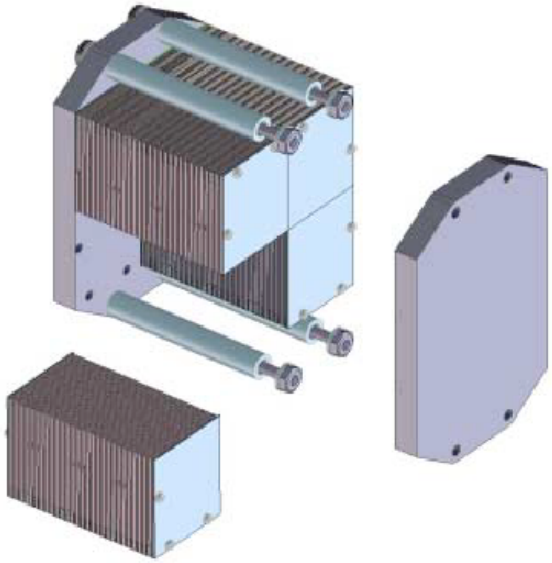
Van derMeer scans to measure $\square\square^*$ (at PHENIX)



…and Shower Max Detector ->independent measurement of displacement and crossing angle

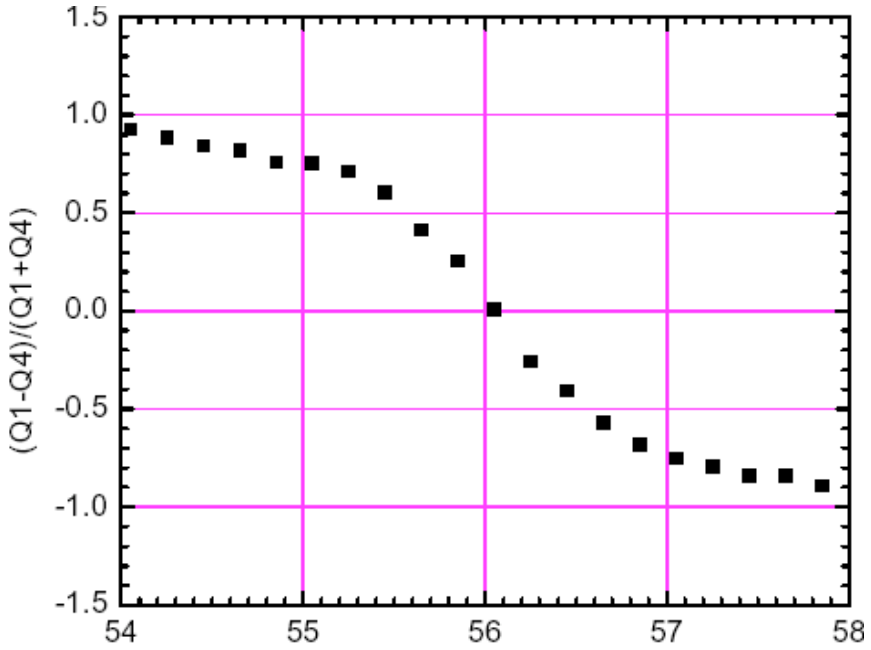


Implementation in ATLAS



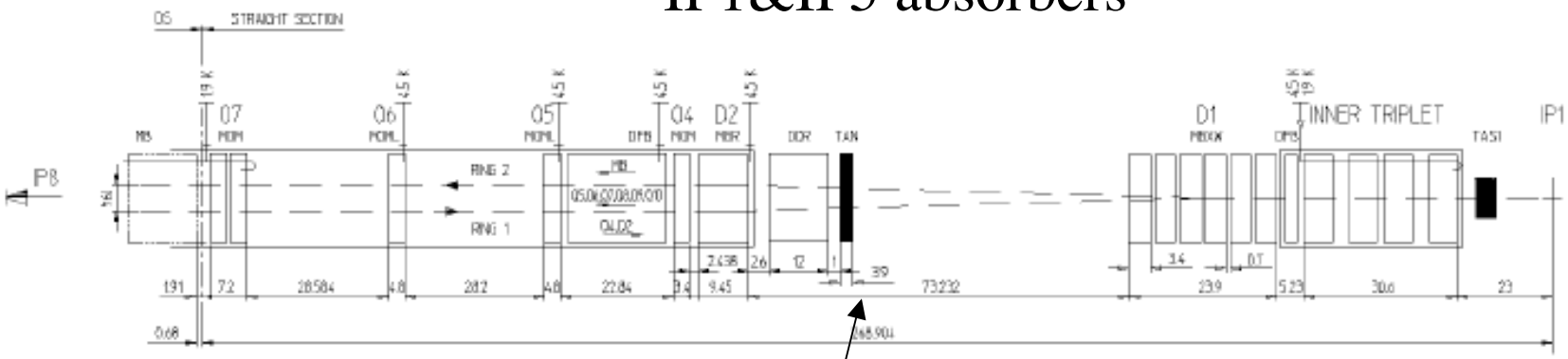
LARP proposed luminometer
4 quadrant High Pressure ionization
Chamber , occupies ~15 cm of TAN
Absorber slot

Asymmetries used to
Measure beam steering



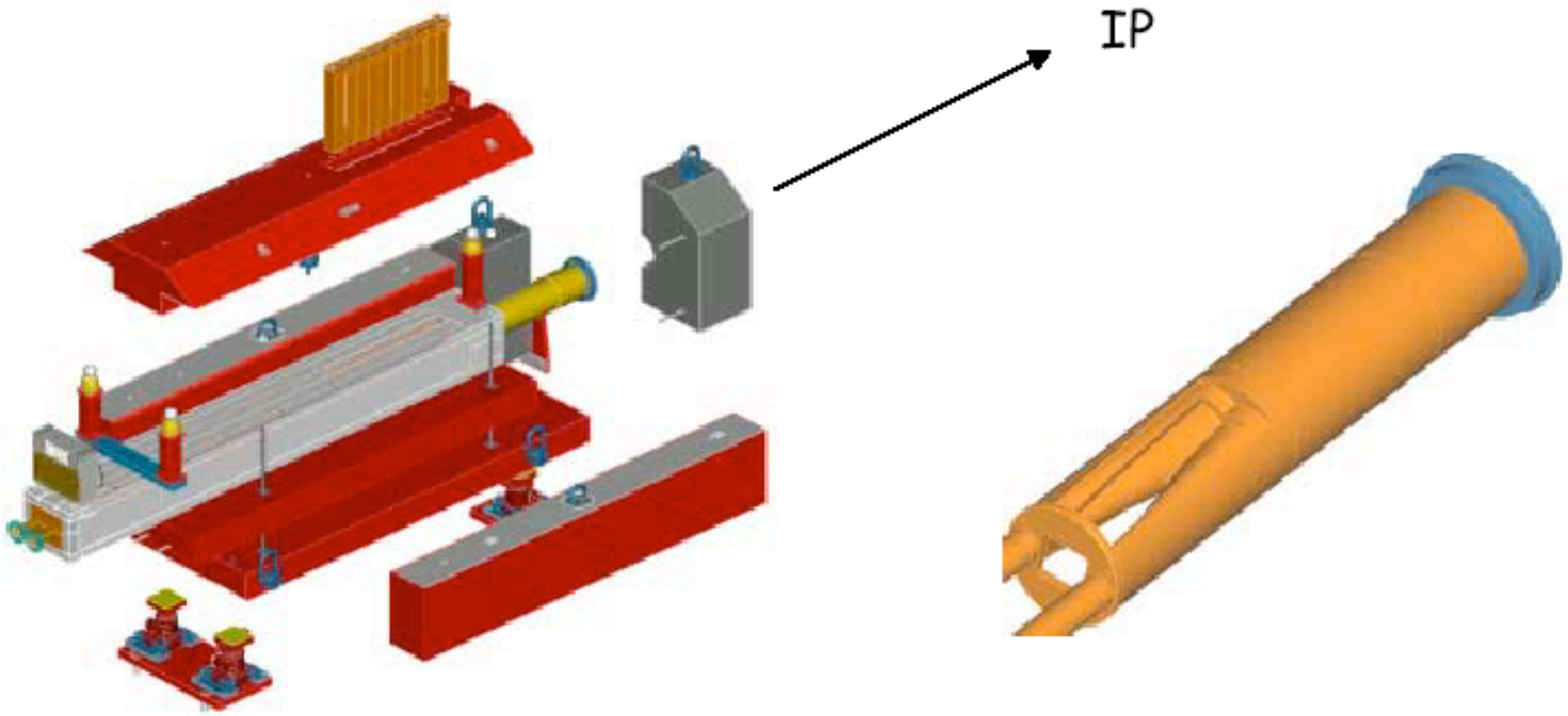
Beam position (cms)

IP1&IP5 absorbers



TAN@140m

Exploded view



Electromagnetic Interactions of Heavy Ions:

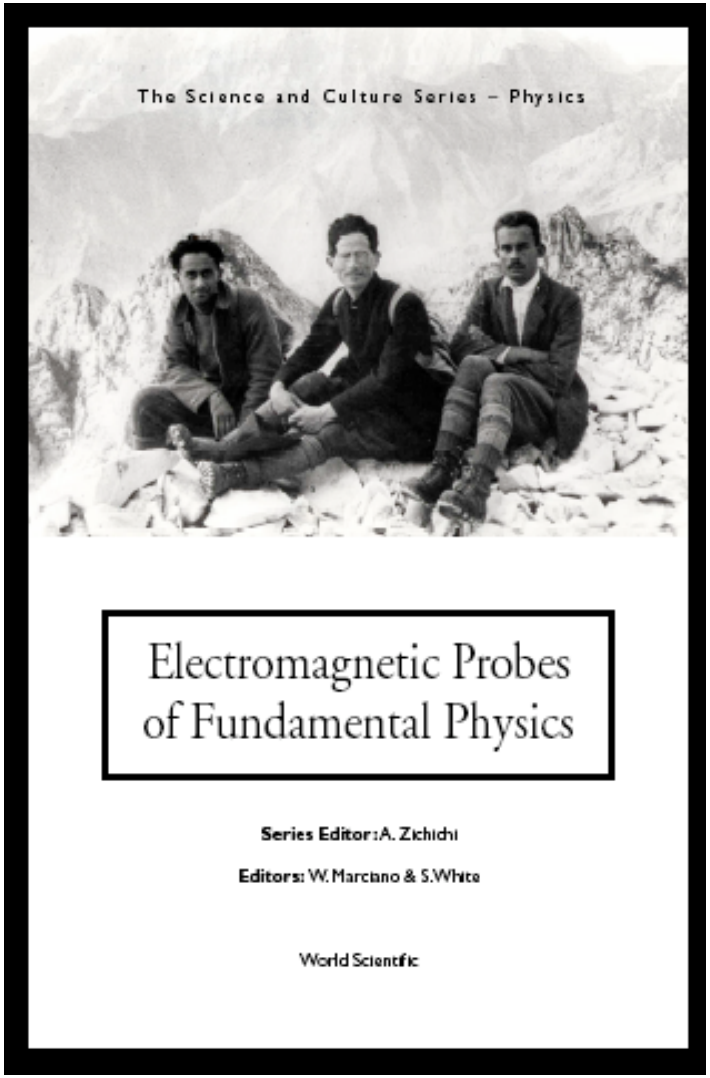
('24)-E.Fermi develops Equivalent □approx for int of e^- and □'s with atoms

('33) -Weiszacker and Williams

(50's) demonstration of EPA with interactions of ~500 MeV e^- with Nuclei- (Wilson, Panofsky et al. @ Stanford)

(80-90's) -first measurement of EM interaction using ion beams @Bevalac SPS and AGS

('03->)- "rapidity gap" physics w. Heavy Ions @ RHIC & LHC



□□□and DPE exchange roles in pp and PbPb

Z^2(or Z^4) vs. $A^{0.3}$ *$B^{0.3}$

p-p

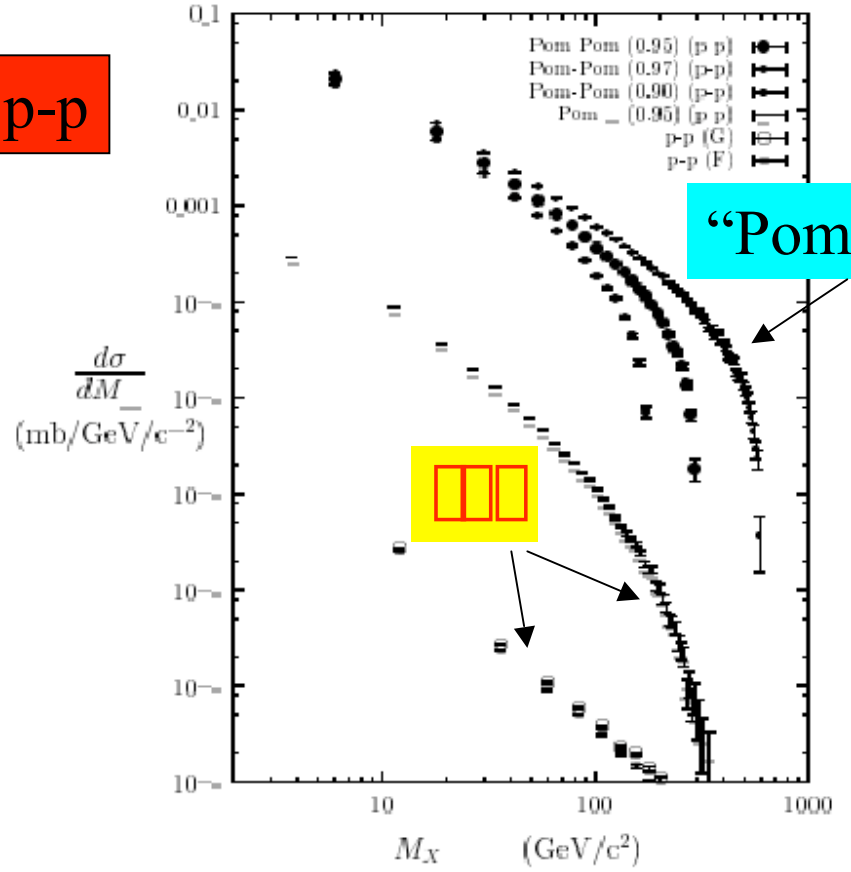


Fig. 4. We compare the cross section for the production of a hadronic cluster of invariant mass M_X via photon-photon interaction in proton-proton collisions using two different methods (F) and (G) to calculate the photon flux, described in the Appendix with the corresponding cross section for the diffractive reactions. The central diffraction cross sections (pomeron-pomeron collisions) are given for three different kinematical cuts $M_{cd} >$ 2 GeV/c^2, c = 0.90, 0.95 and 0.97. The single diffraction photon-pomeron cross section is given for $M_{\gamma\mathbb{P}} > 2$ GeV/c^2 and c = 0.95

Pb-Pb

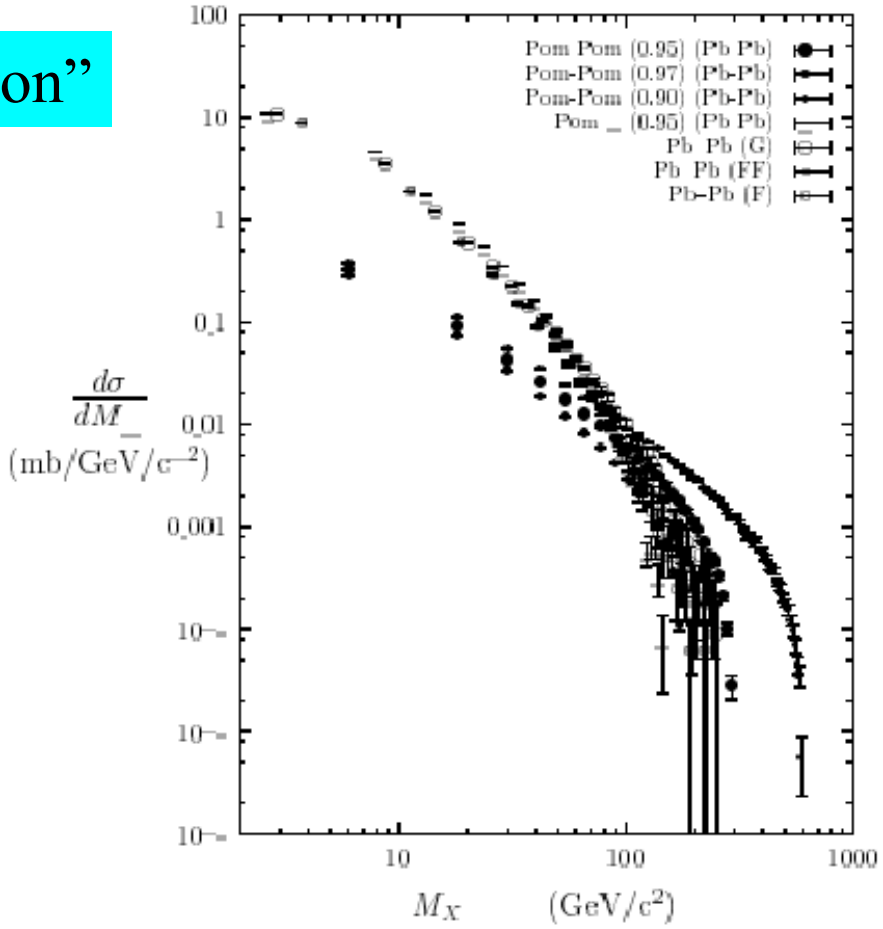
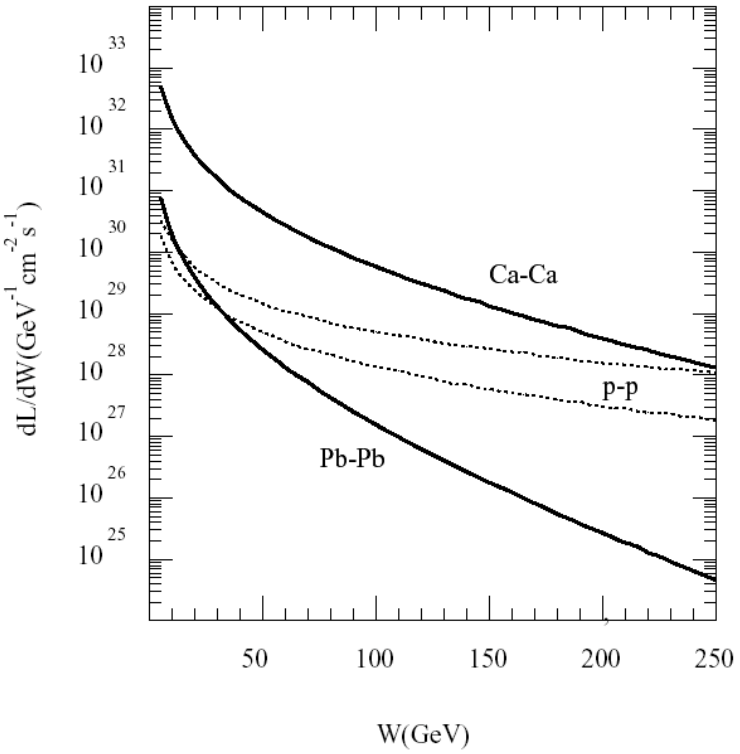
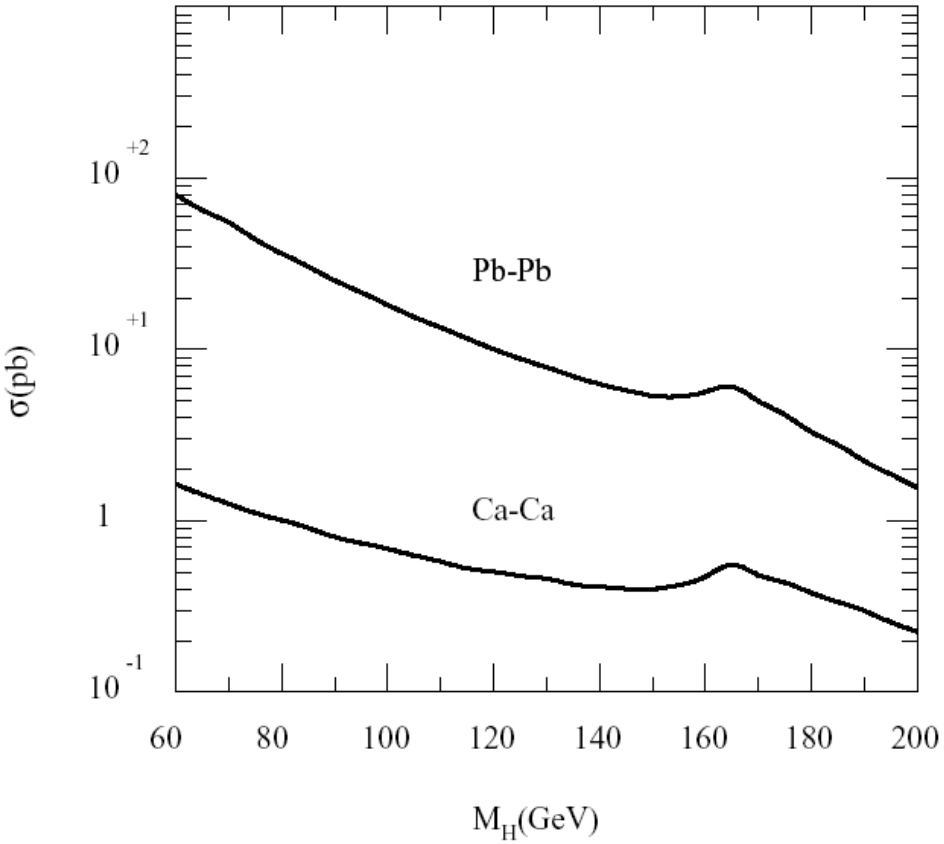


Fig. 9. As Fig. 4 but for heavy ion reactions Pb-Pb



Luminosities based on LHC design parameters

E.Papageorgiu hep-ph/9503372



Low mass Higgs production

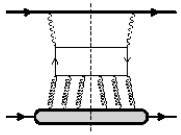
cross section=flux*(->H^0)

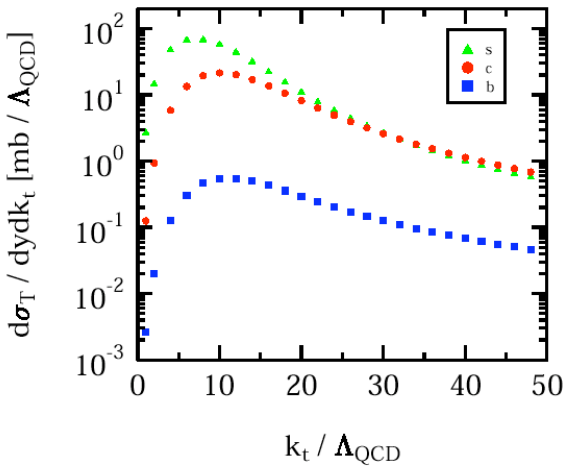
Fixed target □beam w. E□>100TeV

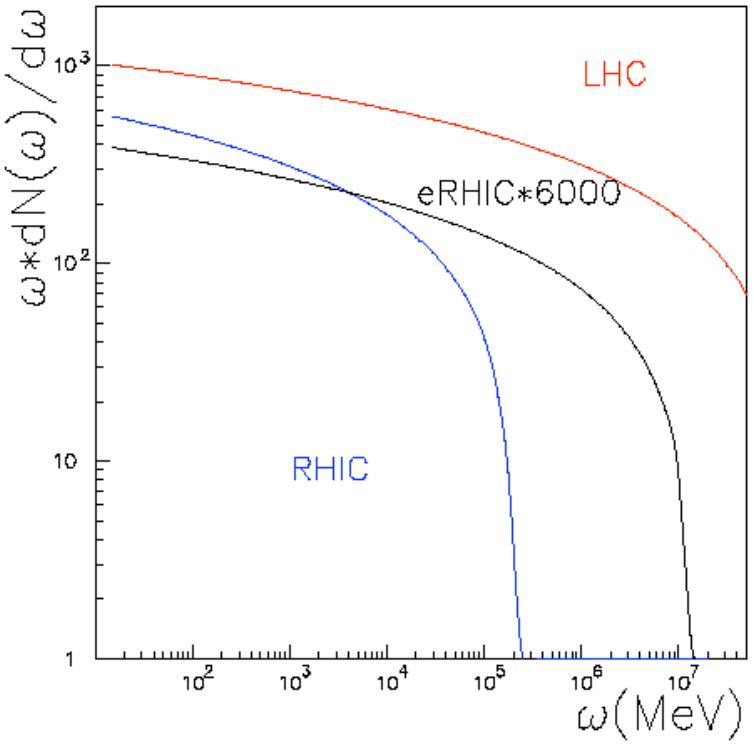
qq photoproduction in the Color Glass Model

test parton distribution (saturation scale Q_s)

1) average number of qq pairs
[Gelis, Peshier, hep-ph/0107142]







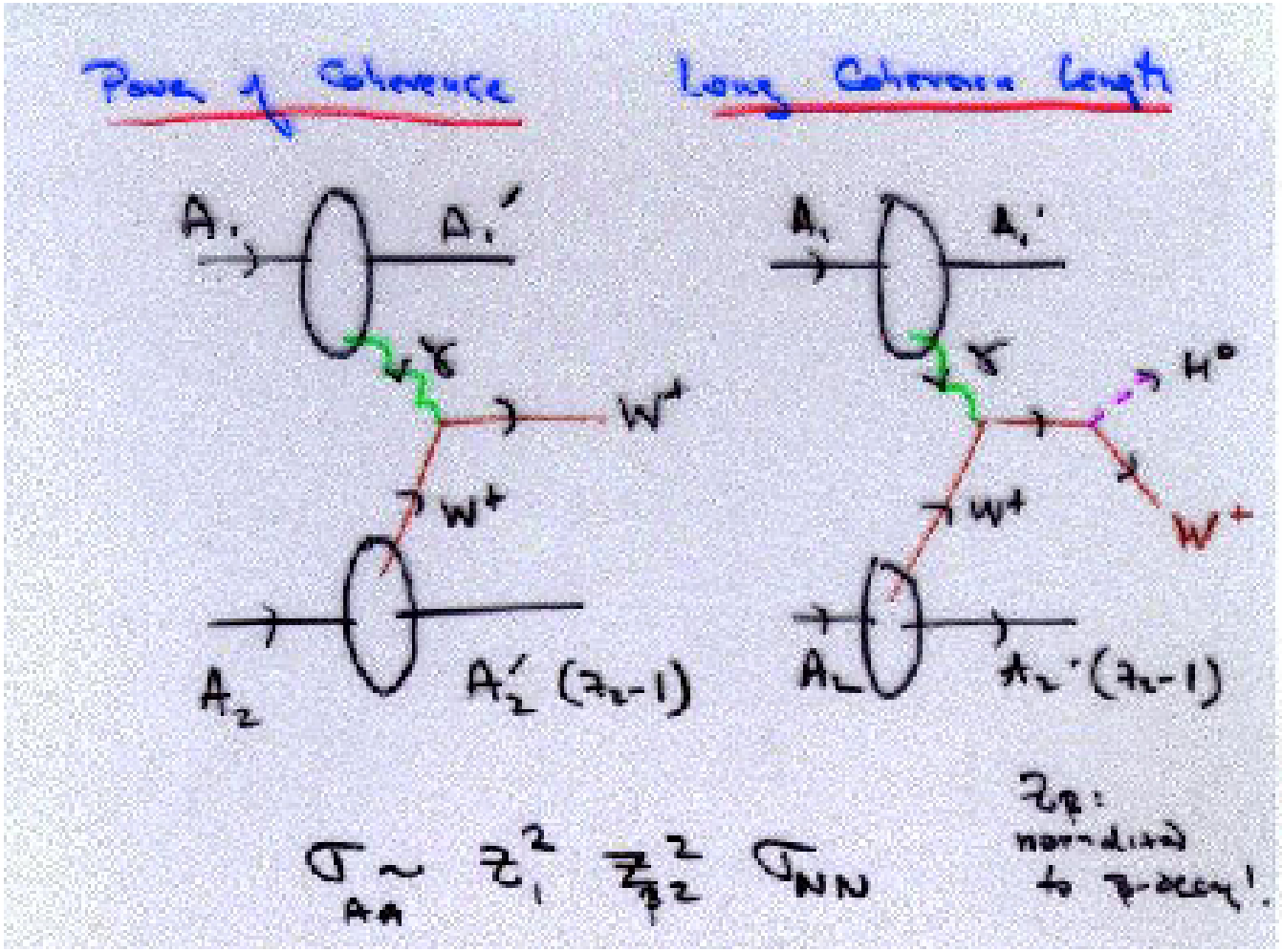
AuAu, $\gamma = 3000$, $Q_s = 2$ GeV (k_t: transv. momentum of the pair)

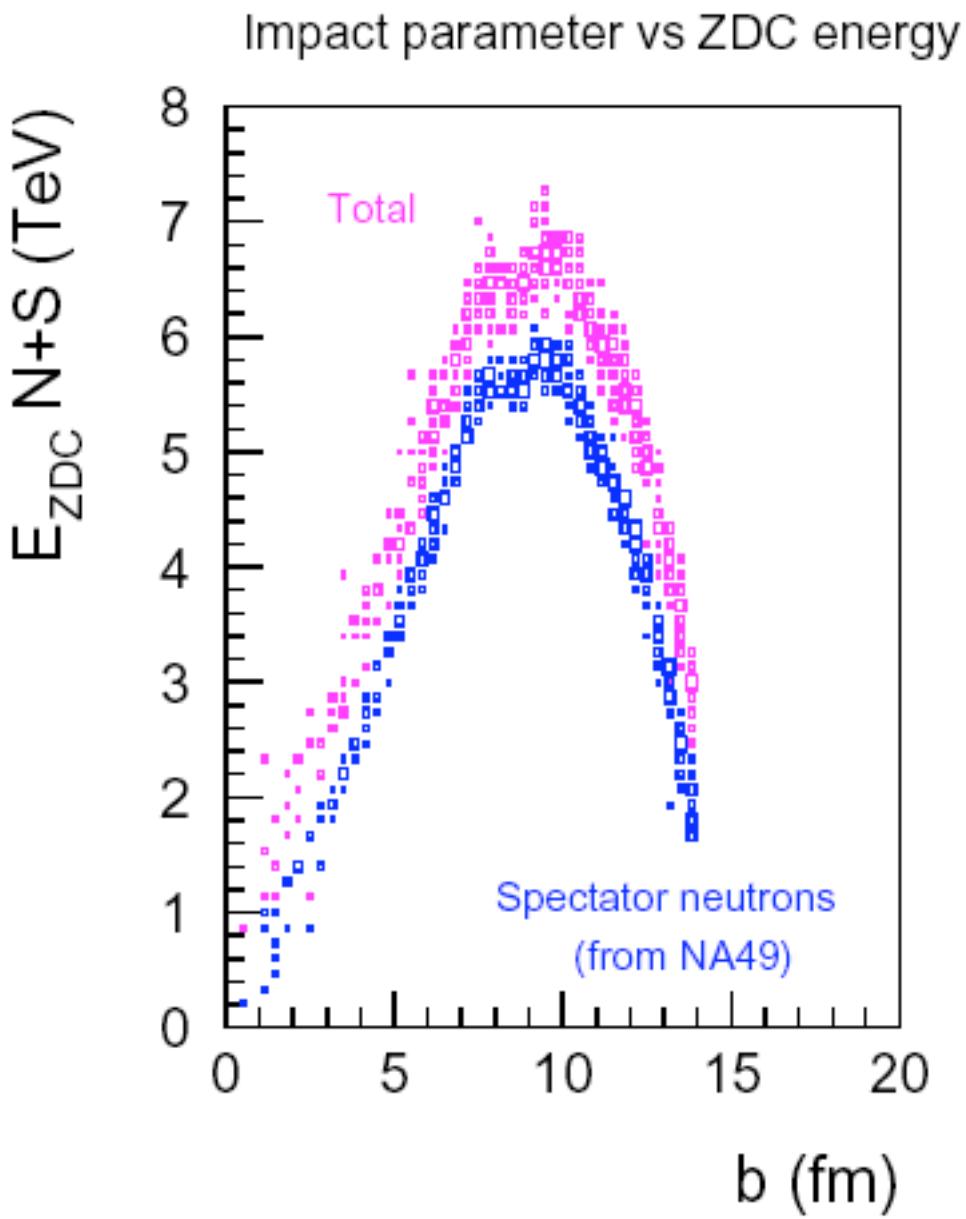
distinct peak in spectrum: $k_t^{\max} \approx Q_s$ (for heavy flavors)

Heavy Ion Physics ca. 2008

Heavy Ion Physics= Opportunities with a tool that we are just learning to exploit
(c.f. e^+e^- physics)

LHC energy scale




Impact parameter vs ZDC energy
E_{ZDC} N+S (TeV)
Total
Spectator neutrons
(from NA49)
b (fm)
0
1
2
3
4
5
6
7
8
0
5
10
15
20

summary

- Beam tagging is a feature of the RHIC Heavy Ion programme
- Similar Instrumentation will be available at LHC
- Increase in energy at LHC significant
  - Hard processes in peripheral events
  - Will complement the pp forward physics program